International Journal of Biology Sciences

ISSN Print: 2664-9926
ISSN Online: 2664-9934
Impact Factor: RJIF 5.45
IJBS 2022; 4(1): 50-54
www.biologyjournal.net
Received: 08-01-2022
Accepted: 09-02-2022

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Assessment of water quality around Odi, Sampou and Agbede Upper Nun River, Bayelsa State Nigeria

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DOI: https://doi.org/10.33545/26649926.2022.v4.i1a.54

Abstract
Assessment of water physico-chemical parameters of surface water in a section of the Upper Nun River, around Agbere, Sampou and Odi, in Bayelsa State, Nigeria was carried out. Water samples were collected biweekly in triplicates for three months using water sampling bottles. The physicochemical water quality parameters determined in this study includes Salinity, Electrical Conductivity (EC), Total dissolved solids (TDS), Total suspended solids (TSS), Total alkalinity (TA), Total hardness (TH), Turbidity, pH, Chloride (Cl), Sulfate (SO_4), Nitrate (NO_3), Iron (Fe), Manganese (Mn), Magnesium (Mg), Bicarbonate (HCO_3), Calcium (Ca), Sodium (Na) and Potassium (K). Salinity and pH, were measured in-situ while others were analysed in the laboratory. The study used the Completely Randomized Design. A one-way ANOVA was used to show variance between the means at (p<0.05), using, Statistical package for social sciences software version 25. Result of the study were in ranges; 6.273-6.810 (pH), 0-0.020 mg/l (Sal), 8.240-48.027 uS/cm (EC), 18.720-28.360 NTU (Tur), 4.123 – 26.917 mg/l (TDS), 0.08-0.54 mg/l (TSS), 0.00-1.00 mg/l (HCO_3), 0.038-0.099 mg/l (SO_4), 0.126 – 0.24 mg/l (NO_3), 7.33-16.33 mg/l (Cl), 3.953-8.843 mg/l (Ca), 0.923-2.687 mg/l (Mg), 1.647-4.437 mg/l (Na), 0.383-1.730 mg/l (K), 0.122-0.159 mg/l (Fe), 5.57 – 8.60 mg/l (TA), 10.933 – 18.90 mg/l (TH), 0.010-0.021 mg/l (Mn). Conclusively, the water is not in its best quality since some of the parameters surpassed their permissible limits. It is therefore recommend that there should be an alternative source of drinking water for the local people within affected axis of the Nun river. Meanwhile proper refuse disposal methods as well as the discouragement of pier toilets in the water body is advocated.

Keywords: Physicochemical parameters, assessment, water quality, sediment quality

Introduction
Water is a vital component to the sustenance of all living organisms (Dirican, 2015, Aghoghovwia *et al.,* 2018) [5]. The physiochemical and biological features of a given water body, determines the productivity of such water (Aghoghovwia *et al.,* 2018) [5]. Most substances that fall on water, quickly settle to bottom sediment – making it a probable major pollutant recipient. The anthropogenic activities and other factors in nature, invariably cause contamination of the water column especially the locals who build pie toilets on aquatic mileu (Seiyaboh *et al.,* 2016) [22]. There exists the threat of the contaminants (physiochemical parameter) surpassing their permissible limits and thereby unlashing mayhem to living organisms that abound in the aquatic milieu. Many physiochemical parameters in the water are known to be essential variables that influence fish distribution and migration, (Ama-Abasi and Akpan, 2011) [6]. The monitoring of water quality is therefore expedient in order to ascertain the status of the streams, Rivers ot water bodies especially those that are constantly receiving entry of contaminants due to industrialization and population explosion (Ite *et al.,* 2013; Taiwo *et al.,* 2012; Patil *et al.,* 2012) [24]. Available information of physicochemical characteristics of the upper Nun river around Odi, Sampou and Agbere axis of Bayelsa State, Nigeria are hardly captured in chronograph. The study therefore, assessed the levels of some physicochemical parameters of the Upper Nun River water to know if they are within or above specific permissible limits specified by relevant bodies.

Materials and Methods
Study Area: The study was conducted at the Odi, Sampou and Agbere axis of the Upper Nun River in Bayelsa State. Sampou and Odi are communities in Kolokuma/Opukuma Local Government Area (LGA) while Agbere is in Sagbama Local Government Area.

The River Nun is coordinate latitude, 5° 0^1 37.31^1 and longitude $6°17^1$$38.58^1$. The river transverses the aforementioned three (3) communities and serve many purposes to the locals. These include fishing, dredging, gravel mining, farming along the River bank, refuse dump site, transportation, laundry among others.

Sampling Techniques
Triplicate water samples were collected at the three different sampling sites.

Sampling Collection
Samples were collected using sterile two (2) litre Mrs capacity labelled plastic bottles with screw cap 30cm depth and taken to the laboratory for analysis (Obasahan and Orosanye 2000).

Analysis procedure
Some of the physicochemical properties such as pH, conductivity, Total dissolved solids, Turbidity, Total suspended solids and salinity were analyzed in-situ by means of their respective probes. On the other hand, total hardness, nitrate, alkalinity, bicarbonate, sulphate, calcium, magnesium, sodium, potassium, manganese and iron were analyzed using the methods of Adeoroti (1996) and AHPA (1998).

Statistical analysis
One-way analysis of variance was used to compare the means across the various stations at a level of significance (p<0.05). Spearman's rho correlation was used to determine the relationship between the parameters. The statistical packages for social sciences software version 20 was used for statistical analysis.

Table 1: The mean and standard deviation of the parameters across the stations

Parameters	Agbere Station 1	Agbere Station 2	Agbere Station 3	Sampou Station 1	Sampou Station 2	Sampou Station 3	Odi Station 1	Odi Station 2	Odi Station 3
pH	6.797±0.009fg	6.780±0.006f	6.810±0.006g	6.360±0.006c	6.340±0.006c	6.497±0.009e	6.310±0.006b	6.400±0.006d	6.273±0.003a
Sal (mg/l)	0.000±0.000a	0.000±0.000a	0.017±0.003c	0.020±0.000c	0.020±0.000c	0.017±0.003c	0.017±0.003c	0.010±0.000b	0.020±0.000c
Cond (uS/cm)	9.540±0.006b	8.240±0.006a	35.440±0.00e	44.310±0.00g	31.500±0.006c	33.540±0.00d	44.193±0.09g	43.797±0.009f	48.027±0.00h
Tur (NTU)	27.550±0.00h	24.850±0.006f	26.750±0.00g	18.963±0.00b	21.550±0.006e	28.360±0.006i	20.153±0.00d	18.720±0.01a	19.917±0.02c
TDS (mg/l)	4.773±0.003b	4.123±0.003a	17.740±0.02e	22.157±0.003f	15.753±0.003c	16.773±0.00d	22.130±0.070f	26.917±0.02h	24.013±0.01g
TSS (mg/l)	0.540±0.006h	0.487±0.007g	0.377±0.003e	0.500±0.006g	0.167±0.003b	0.083±0.003a	0.290±0.006c	0.410±0.006f	0.310±0.006d
NO3 (mg/l)	0.127±0.001a	0.127±0.001a	0.132±0.001b	0.126±0.001a	0.132±0.001b	0.240±0.002d	0.128±0.001a	0.137±0.000c	0.127±0.001a
Cl (mg/l)	10.333±0.33b	10.000±0.00b	8.000±0.000a	7.333±0.333a	8.000±0.000a	16.333±0.33d	10.333±0.33b	12.000±0.00c	7.333±0.333a
SO4 (mg/l)	0.054±0.001d	0.057±0.002d	0.049±0.001b	0.038±0.001a	0.051±0.002bc	0.099±0.002f	0.056±0.001d	0.064±0.001e	0.041±0.001a
HCO3 (mg/l)	0.000±0.000a	0.000±0.000a	0.533±0.033c	0.400±0.000b	0.500±0.000c	1.000±0.000e	0.500±0.000c	0.600±0.000d	0.500±0.000c
TA (mg/l)	6.467±0.033b	7.867±0.067d	8.600±0.058e	7.233±0.145c	6.700±0.000b	8.433±0.033e	7.000±0.000c	5.567±0.120a	7.000±0.000c
TH (mg/l)	13.800±0.05c	15.500±0.05e	18.900±0.05f	12.867±0.03b	12.833±0.088b	12.967±0.03b	10.933±0.03a	13.000±0.00b	14.367±0.08a
Ca (mg/l)	5.180±0.012d	5.098±0.002c	4.357±0.017b	3.953±0.163a	4.343±0.003b	8.843±0.163f	5.523±0.164d	6.420±0.012e	4.060±0.142b
Mg (mg/l)	1.813±0.018e	1.533±0.158d	1.300±0.012b	0.923±0.148a	1.340±0.006ab	2.687±0.007f	1.280±0.012ab	1.677±0.015de	1.180±0.012b
Na (mg/l)	2.573±0.018cd	2.603±0.033d	2.183±0.009b	1.647±0.257a	2.260±0.006bc	4.437±0.077f	3.647±0.015e	3.470±0.006e	2.183±0.009b
K (mg/l)	0.800±0.012cd	0.860±0.006cd	0.870±0.006d	0.713±0.093bc	0.727±0.009bcd	1.730±0.085f	0.383±0.007a	1.233±0.020e	0.600±0.023b
Fe (mg/l)	0.233±0.003b	0.180±0.012ab	0.170±0.015a	0.213±0.035ab	0.183±0.009ab	0.187±0.007ab	0.193±0.007ab	0.193±0.007ab	0.210±0.006ab
Mn (mg/l)	0.021±0.001a	0.018±0.000a	0.015±0.002a	0.014±0.001a	0.015±0.001a	0.050±0.035a	0.010±0.000a	0.015±0.001a	0.017±0.001a

Water
Water is vital for the survival of life on earth. The accessibility of water plays a substantial role in the location, and actions of human beings, because growth explosion is placing great demands on natural fresh water resources (Waziri and Ogugbuaja, 2010) [26]. For a given river the water quality depends on so many interrelated parameters with local and temporal variation which are influenced by the water flow during the year (Mandal *et al*., 2010) [15]. In this study, the water quality parameters are seen to have differed across the various stations, hence the different water qualities at the three locations.

pH
The pH was within the values of 5.80-7.57 recorded in Epie Creek (Ben-Eledo *et al*., 2017) [12], and 5.53-6.85 reported by Ogamba *et al*., (2015b) [17] from Ikoli Creek and also 6.61-7.50 in Kolo Creek (Aghoghovwia and Ohimain, 2014) [4]. But lower than the ranges of 7.19-7.89 and 6.89-7.53 for wet and dry season in Usuma River which Ugwu and Wakawa, (2012) [25] reported. The pH values of this study were similarly lower than ranges of 7.27-7.47 in Oni River (Andem *et al*., 2012) [8], ranges of 7.11-7.32 forIgbedi Creek (Seiyaboh *et al*., 2013b), 7.4 -8.9 recorded in Egbe Reservoir (Edward and Ugwumba, 2010) [14], 7.3-8.4 in Awba Reservoir which was reported by (Anago *et al*., 2013) [7] and finally 7.2 in Taylor Creek (Daka *et al*., 2014) [13]. However, the value from this study lies within the permissible limit of as 6.5-8.5 given by W.H.O (1984) [27] and NDWQ (SON 2007) [23].

Salinity
The salinity concentration recorded in this study which lies within the range of 0 -0.020 mg/l is similar to 0.03 mg/l reported for the Nun river at Gbarantoru and Tombia axis (Aghoghovwia *et al.,* 2018) [5] but lower when compared to the range of 0.03 – 0.04 mg/l which was reported for Kolo Creek (Aghoghovwia and Ohimain, 2014; Ogamba *et al*., 2015a) [4], 0.12 – 2.58 mg/l observed in Epie Creek by Ben-Eledo *et al.,* (2017) [12], but falls within the range of 0.00 – 0.050 mg/l reported in the Nun river at Amassoma axis (Agedah *et al*., 2015; Ogamba *et al*., 2015c) [2, 18] and the Range of 0.01 – 0.03 mg/l in Ikoli Creek (Ogamba *et al.,* 2015b) [17]. However, the similarity of the value of salinity across the various stations shows that the water is homogeneous, that is to say, it is freshwater (Ben – Eledo *et al*., 2017) [12].

Electrical Conductivity
The Electrical Conductivity of the water samples as reported in this study ranged from 8.240 – 48.027 uS/cm. This level is higher than Electrical Conductivity of 0.58 µS/cm 0.78 µS/cm, and 0.64 µS/cm in Doma, Farinruwa and Mada Rivers respectively, during dry season and 0.31 µS/cm, 0.33

µS/cm, 0.34 µS/cm during wet season respectively (Aremu *et al*., 2011) [11]. But lower than the value range of 59.70-71.65µS/cm in the Nun River (Aghoghovwia *et al.,* 2018) [5], 270.35µS/cm -297.56 µS/cm in Ona river which was reported by Andem *et al*., (2012) [9], 81.30 µS/cm-299.00 µS/cm for Usuma Dam, and range of 82.30-102.00 µS/cm reported by Aghoghovwia and Ohimain (2014) [4]. The EC value in this study is below the permissible limit for Electrical Conductivity given by (SON 2007) [23] and WHO (1984) [27] as 1000µS/cm.

Turbidity

The Turbidity value reported for the water sample in this study ranged from 18.720 – 28.360 NTU, and is therefore lower than the range of 35.95 – 82.32 NTU Seiyaboh *et al*., (2013) reported in Igbedi Creek, 25.70-117.252 NTU recorded in Nun River at Amassoma axis according to Agedah *et al*., (2015) [2] and Ogamba *et al*., (2015c) [18], 27.37-40.5 NTU as was reported by Agedah *et al*., (2015) [3] and Ogamba *et al*., (2015c) [18], 31.29-105.04 NTU which was reported by Ben-Eledo *et al*., (2017) [12] for Epie Creek, as well as 27.37-40.5 NTU recorded for Kolo Creek (Aghoghovwia and Ohimain 2014) [4] and much lower than the mean value of 58.96 NTU obtained in Taylor Creek, but on the other hand it is similar to the value of 18.52-18.99 NTU recorded by Aghoghovwia *et al*., (2018) [5] in the Nun river at Gbarantoru and Tombia axis. However, the value range is higher than the permissible limit of 5NTU for drinking water quality given by WHO (1984) [27] and (SON 2007) [23]. This implies that the Nun river at this stations is highly turbid, and is not fit for drinking. This is due to the high rate of farming activities observed across the stations, as well as sand mining and other related anthropogenic activities.

Total dissolved Solids

The TDS range of 4.123 – 26.917 mg/l was recorded across the stations and is lower than the value of 29.83.83 mg/l observed in Nun River (Aghoghovwia *et al*., (2018) [5], 33.00-546.50 mg/l reported for Epie Creek (Ben-Eledo *et al*., 2017) [12], 48.80 mg/l -179.50 mg/l and 168.90 mg/l - 465.20 mg/l during dry and wet seasons respectively in Usuma dam (Ugwu and Wakawa, 2012) [25], 41.45-51.00 mg/l which was reported in Kolo Creek (Aghoghovwia and Ohimain 2014) [5]. Meanwhile the value is above the value of 0.02 mg/l -2.28 mg/l in Egbe Reservoir, reported by Ugwumba (2010) [14], but it is below the permissible limit of 500 mg/l (SON 2007) [23] and WHO (1984) [27].

Total Suspended Solids

The TSS range of 0.08 – 0.54 mg/l was recorded across the stations, and when compared with previous works, is lower than the range of 1.96-2.13 mg/l in the Nun river at Gbarantoru and Tombia axis, 3.74-10.562 mg/l in Epie Creek by Ben-Eledo *et al*., (2017) [12], 3.43-5.47 mg/l (Ogamba *et al*., 2015c) [18], 1.75-3.42 mg/l in Kolo Creek (Ogamba *et al*., 2015a), whereas it is higher than range of 0.05-0.25 mg/l which was recorded by Aghoghovwia and Ohimain (2014) [5]. On the other hand, it is lower than the permissible limit as given by Canadian Drinking Water Quality (1978) is 10.0 mg/l.

Bicarbonate

The Bicarbonate level range of 0.00-1.00 mg/l was recorded across all locations which is within the range of 0.97-1.43 mg/l in the Nun river at Gbarantoru and Tombia axis (Aghoghovwia *et al*., 2018) [5], but lower than the range of 2.18-4.28 mg/l in which Ben-Eledo *et al*., (2017) [12] recorded for Epie Creek.

Sulphate

The Sulfate concentration range of 0.038 – 0.099 mg/l was recorded across all stations. In comparison, it is lower than the range of 6.50-14.30 mg/l in Epie Creek (Ben-Eledo *et al*., 2017) [12], 1.79-2.53 mg/l by Aghoghovwia *et al*., (2018) [5] in Nun river at Gbarantoru and Tombia axis, 6.09-8.83 mg/l as was reported by Seiyaboh *et al*., (2013b) in Igbedi Creek, 1.4-3.50 mg/l in Ikoli creek (Ogamba *et al*., 2015b) [17]. Nevertheless, the value is lower than 0.57-0.87 mg/l in Amasosoma axis of the Nun river, (Ogamba *et al*., 2015c) [18] as well as as 0.1-0.57 mg/l in Kolo Creek (Ogamba *et al*., 2015a). The value is within the permissible limit of 500 mg/l (SON 2007) [23].

Nitrate-N(NO_3)

Nitrate(NO_3) is the major form of nitrogen found in naturalwaters and is one of the common pollutants in surface water (Jagessar and Sooknundun, 2011). Its value range in this study was 0.126 – 0.24 mg/l. in comparison, this range is lower than 0.63-1.69 mg/l Ben-Eledo *et al*., (2017) [12] reported in Epie Creek, 0.32-4.15 mg/l recorded by Seiyaboh *et al*., (2013a) at the Tombia bridge construction area, 0.63-1.69 mg/l in Kolo creek (Agedah *et al*., 2015; Ogamba *et al*., 2015c) [3, 18], but similar to 0.18-0.35 mg/l in the Nun river at Gbarantoru and Tombia axis (Aghoghovwia *et al*., 2018) [5], 0.10-0.24 mg/l in Kolo Creek (Aghoghovwia and Ohimain, 2014; Ogamba *et al*., 2015a) [4], 0.12-0.26 mg/l in Ikoli Creek (Ogamba *et al*., 2015b). However, the value is with a little margin higher than 0.0.9-0.226 mg/l (Seiyadon *et al*., 2013b) in Igbedi Creek, but fall within the permissible limit for drinking water but above the limit permitted for aquatic life which are 10.0 mg/l and 0.06 mg/l (WHO, 1984; SON 2007) [27, 23]. With respect to nitrates, the water is safe for dinking as increased levels of nitrates often indirectly harm the environment by causing bacterial growth and huge algae blooms (Yanamadala, 2005). Nitrate levels of over 5mg/l indicate man-made pollution and become extreme at 200mg/l (Bellingham, 2012).

Chloride

The Chloride range of 7.33 – 16.33 mg/l recorded in this study compares favourably with 11.10-14.33 mg/l documented lower Nun river at Gbarantoru and Tombia axis (Aghoghovwia *et al*., 2018) [5], and however higher than 0.36-0.46 mg/l in Igbedi Creek (Seiyaboh *et al*., 2013b), 1.60-3.40 mg/l in Ikoli Creek (Ogamba *et al*., 2015b) [17], 1.257-1.467 mg/l in Kolo Creek (Ogamba *et al*., 2015a) and 0.50-3.47 mg/l in the Nun river (Ogamba *et al*., 2015c) [18]. Chloride is non-toxic to humans, although there is a secondary drinking water standard of 250 mg/l above which it can give rise to detectable taste in water, but the threshold depends upon the associated cations (Saxena *et al*., 2016). It is within the permissible limit of 250 mg/l for drinking water but higher than 1.10 mg/l (2.0 ug/l) (health and welfare Canada, 1979a) for aquatic life. The chloride level in this study does not support aquatic life but safe for drinking with respect to chloride.

Calcium (Ca)
The Calcium values range of 3.953 – 8.843 mg/l were recorded which are within the range of 7.05-9.20 mg/l recorded by Aghoghovwia *et al*., (2018) [5] in the Nun river at Gbarantoru and Tombia axis, but higher than 0.80-2.33 mg/l in the lower Nun river, Amassoma axis (Ogamba *et al*., 2015c) [18], 1.107-1.83 mg/l in Kolo Creek (Ogamba *et al*., 2015a) [17] and 3.78 mg/l recorded for Taylor Creek (Daka et al., 2014) [13]. The permissible limit of calcium of <1000 mg/l was given by WHO (1984) [27]. Although the Calcium level of the study area was within permissible limit, it is high compared to the other values gotten from other recent works. This can be attributed to high cations exchange in the water (Ben-Eledo *et al*., 2017) [12].

Magnesium (Mg)
The level of magnesium obtained range between 0.923 – 2.687 mg/l and is within the range of 0.39-14.66 mg/l in the lower Nun river at Amassoma axis (Ogamba *et al*., 2015c) [18], 1.92-3.17 mg/l in the lower Nun river at Gbarantoru and Tombia axis (Aghoghovwia *et al*., 2018) [5], but higher than 0.37-0.5 mg/l observed in Kolo Creek (Ogamba *et al*., 2015a) [17], whereas the Magnesium range of 3.07-10.46 mg/l in Epie Creek (Ben-Eledo *et al*., 2017) [12] is higher than the level observed in this study area. The magnesium value in this study is higher than the permissible limit of 0.2 mg/l (SON, 2007) [23].

Sodium (Na)
The level of Sodium recorded span between 1.647 – 4.437 mg/l but were however lower than the range of 3.55-4.84 mg/l, 2.27-16.02 mg/l in Epie Creek (Ben-Eledo *et al*., 2017) [12], 7.42 mg/l in Taylor Creek (Daka *et al*., 2014) [13], but higher than 0.55-1.31 mg/l for the Amassoma axis of the Nun river, 0.58-0.68 mg/l in Kolo Creek (Ogamba *et al*., 2015a) [17]. However, it is below the permissible limit of 200 mg/l (SON 2007, WHO, 1984) [23, 27].

Potassium (K)
The concentration of Potassium generated ranged from 0.383 – 1.730 mg/l which is similar to 1.17-1.38 mg/l in the Nun river at Gbarantoru and Tombia axis, 0.33 – 0.82 mg/l in Nun river Amassoma axis (Ogamba *et al*., 2015c) [18], but lower than 2.24 – 5.26 mg/l in Epie Creek (Ben-Eledo *et al*., 2017) [12], and higher than 0.31 – 0.36 mg/l documented in Kolo Creek by Ogamba *et al*., (2015a) [17].

Iron (Fe)
Iron is one of the most abundant elements in the earth's crust with variable oxidation states of 2 and 3 as in $Fe2^{+}$ and $Fe3^{+}$ respectively. The level of Iron ranged between 0.170 – 0.233 mg/l and is somehow similar to Fe values of 0.122-0.159 mg/l obtained in the lower Nun river at Gbarantoru and Tombia axis (Aghoghovwia *et al*., 2018) [5] and 0.137-0.157 mg/l Kolo, Imiringi and Otusega (Ogamba *et al*., 2017) but is within the permissible limit of 0.3 mg/l for drinking water (WHO, 1984) [27].

Total Alkalinity
Total alkalinity refers to the total concentration of bases in water expressed as mg/l of equivalent calcium. Total alkalinity concentration computed, were in ranges of 5.57-8.60 mg/l which also fall within the range of 5.50-13.40 mg/l in the lower Nun river at Gbarantoru and Tombia axis (Aghoghovwia *et al*., 2018) [5]. Values obtained in this study are lower than 19.20 – 62.00 mg/l in Epie Creek (Ben-Eledo *et al*., 2017) [12], 50.64 – 67.61 mg/l in Igbedi Creek (Seiyaboh *et al*., 2013b), 67.76 mg/l -82.64 mg/l in Egbe reservoir (Edward and Ugwumba, 2010) [14]. However, it is within the permissible limit of 20 mg/l (WHO 1984) [27]. The value of total alkalinity sheds light on the acidity of the water medium (Aghoghovwia *et al*., 2018) [5].

Total Hardness
The concentration of Total Hardness of this study ranged between 10.933 – 18.90 mg/l and is comparatively lower than 52.86-280.00 mg/l in Epie Creek (Ben-Eledo *et al*., 2017) [12], 22.20 – 23.30 mg/l in the lower Nun river at Gbarantoru and Tombia axis.Values generated in this experiment are however higher than 0.90 – 3.33 mg/l in the lower Nun river at Amassoma axis (Ogamba *et al*., 2015c) [18], 1.03 – 1.37 mg/l in Kolo Creek (Ogamba *et al*., 2015a) [17]. There was high level of anthropogenic activities across the various stations, which could have led to the differences in Total hardness across the stations. Nonetheless, Total hardness value is within the permissible limit of 800 mg/l (WHO 1984) [27].

Manganese
Manganese is essential for normal physiological functioning of humans and animals and exposure to low levels of manganese in the diet is considered nutritionally essential in humans (Mebrahtu and Zebrabruk, 2011). The level of Manganese was found to range from between 0.010 – 0.021 mg/l which is higher than the value of 0.017 mg/l recorded for Kolo Creek at Kolo and 0.013 mg/l recorded for both Otusega and Imiringi parts of Kolo Creek (Ogamba *et al*., 2017). Manganese values in this experiment islower than 0.05 mg/l which is the permissible limit for Manganese given by (SON, 2007) [23].

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